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THE EFFECT OF STADIS 450 ON MSEP RATING AND COALESCENCE

TECHNICAL BASIS OF RE-DOPING TURBINE FUELS WITH STADIS 450

COORDINATING RESEARCH COUNCIL
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The use of filter/coalescers at airports and terminals requires that the fuel be free from additives and contaminants which might reduce the effective service life of these elements. The Microseparometer (MSEP) is one test which is commonly used to ensure that the fuel is free from surfactants. However, experience has shown that the use of Stadis 450 often significantly lowers MSEP rating while not affecting coalescer performance. This has caused problems in situations where re-doping with Stadis 450 to improve the fuel conductivity is needed. In some cases, the MSEP rating due to previous additions of Stadis 450 precludes re-doping without reducing the MSEP to below commonly accepted ratings. This study was undertaken to determine whether there was a correlation between the MSEP rating due to Stadis 450 addition and coalescer deactivation.

Examination of data from field experience, the United States Air Force service tests, and other literature confirmed the hypothesis that Stadis 450 did not adversely affect coalescer performance commensurate with the drop in MSEP rating often seen. A substantial experimental evidence from single element tests similar comparing coalescer performance when ASA-3 was used to those tests when Stadis 450 was used showed slightly better effluent water levels when Stadis 450 was used (3.9 ppm for ASA-3 vs. 2.9 ppm), while the average value of MSEP differed markedly (88.7 for ASA-3 vs. 63 for Stadis 450).

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ABSTRACT (continued)

As a result of this study, it was concluded that the customary minimum MSEP of 70 can be relaxed when a drop in rating is ***specifically due to the addition of Stadis 450***. The data indicate that Stadis 450 will not disarm coalescers even though MSEP may be low. However, there is a need to maintain control over chance contamination which may occur during fuel handling and distribution which could have a deleterious effect on coalescence.

The study recommended to allow re-doping of aviation turbine fuel with Stadis 450 to maintain conductivity within specification provided that depression in MSEP is known to have been caused by Stadis 450. Further work should be done to develop a valid test for measuring contaminants which deactivate coalescers whether or not Stadis 450 is present. This may require reinterpretation of MSEP, modification of the MSEP test, or development of a new test.

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1. Executive Summary

1.1 Introduction

Filter/coalescers are used at airports and terminals to remove water and particulate. The ability of a coalescer to remove water and its effective service life time can be adversely affected by cerain additives and naturally occurring contaminants, e.g., surfactants. One of the fuel tests commonly used to ensure than surfactants are not present in the fuel is the MSEP[1].

The purpose of this report is to determine if there is a relationship between coalescer performance and MSEP when Stadis 450 is added to turbine fuel. This study was necessitated by the fact that re-doping with Stadis 450 for the purpose of increasing conductivity was not possible for some fuels because the initial addition of Stadis 450 depressed the MSEP to levels below 80. Subsequent addition of Stadis 450 would reduce MSEP below 70, a level which is commonly accepted as a minimum for assuring that coalescer performance is not degraded. However, field experience has not shown a deterioration in coalescer performance when Stadis 450 is used even though the MSEP on average is significantly lowered .

When ASA-3 was removed from the market, Stadis 450 became the sole approved static dissipater additive for aviation turbine fuels. A problem arose for some non-hydrotreated fuels in that, after Stadis 450 addition, the conductivity level dissipated over time while the MSEP did not correspondingly recover. While coductivity loss was observed for ASA-3 treated fuels, the conductivity depletion was often accompanied by a corresponding increase in MSEP. Thus, while re-doping with static dissipater additive to increase the conductivity is permitted up to the maximum levels specified in ASTM D-1655[2] and DEFSTAN 91-91[3], the low MSEP when Stadis 450 is used precludes its use since the MSEP would be further depressed.

This study was undertaken to determine whether re-doping with Stadis 450 could be undertaken without regard to MSEP level. Key to this was to show that MSEP due to Stadis 450 is not related to coalescer deactivation.

1.2 Scope

This report examined the effect of Stadis 450 on coalescer performance by:

- Examining field experience data and observation;
- Obtaining experimental evidence from the literature and various qualification tests and investigations.

1.3 Results

1.3.1 Field Experience

Except for one well documented case where Stadis 450 reacted with non-hydrotreated fuels to form a precipitate which deactivated coalescers, it is generally accepted that Stadis 450 does not affect coalescer performance adversely even though MSEP are somewhat lower than with ASA-3 additized fuels. This is based on

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[1]American Society of Testing Materials,"Standard Test Methods for Determining Water Separation Characteristics of Aviation Turbine Fuels by Portable Separometer" D-3948, Annual Book of ASTM Standards Volume 5.03 (1995)

[2]American Society of Testing Materials, "Standard Specification for Aviation Turbine Fuels",D-1655, Annual Book of ASTM Standards Volume 5.01 (1995)

[3]United Kingdom, Ministry of Defense,"Turbine Fuel, Aviation Kerosine Type Jet A-1", DEF STAN91-91 Issue 1 September 1994.

over 15 years of experience in military and commercial use. The recent re-formulation of Stadis 450 is believed to have solved the problem of coalescer deactivation by precipitate formation.

In addition, the United States Air Force conducted a service test of two fuel conductivity additives (ASA-3 and Stadis 450) during the period April 1977 to May 1979. Water separation properties were thoroughly evaluated both in single element and full scale field tests.

General conclusions drawn from this report are:

- Single element tests were satisfactory for fuels which had a majority of ASTM D2550 WSIM ratings below 70 as a consequence of adding both corrosion inhibitor and conductivity improver.
- Fuel WSIM ratings at the airbases during the study period followed a bimodal distribution, with sizable populations between 45-60 and 71-85.
- The effect of conductivity additive on the WSIM rating of fuels already containing corrosion inhibitor and FSII also tended to fall into two population groups.
- When WSIM values less than 70 are obtained as a consequence of adding corrosion inhibitor and/or conductivity additive, satisfactory water separation is achieved. This conclusion presumes that base fuel WSIM is a reasonable value (such as 85 minimum as required in DEFSTAN 91-91) which is generally needed to provide a minimum value of 70 when all military fuel additives are present except conductivity additive. Data tend to support a similar conclusion for the MSEP test, but less definitively because the prototype MSEP test was not carried out at all locations.

1.3.2 Experimental Evidence

There has been substantial research relating WSIM or MSEP to coalescer performance. In general, there is a fairly good relationship between effluent water concentration from a filter/coalescer vessel and WSIM for a wide variety of additives and contaminants. However, at least in one study[4], Stadis 450 was shown to not affect coalescer performance even though MSEP was significantly depressed.

This report compiled a number of single element tests results from a variety of sources. The results were mostly from qualification tests or investigations where high dosages of additives were present. In these studies, fuels with Stadis 450; Stadis 450 and HiTEC 580; Stadis 450, HiTEC 580 and FSII as well as similar tests where ASA-3 was used were compiled and correlated.

For fuels containing Stadis 450:

- The average MSEP was 63 with a standard deviation of 13.8.
- The corresponding water effluent was 2.9 ppm with a standard deviation of 2.8 ppm.

For fuels containing ASA-3:

- The average MSEP was 88.7 with a standard deviation of 10.4.
- The corresponding water effluent was 3.9 ppm with a standard deviation of 2.2 ppm.

Based on these results, it would appear that Stadis 450 does not have an adverse effect on coalescer performance even when MSEP is low.

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[4]Swift, S. T. *Development of a Laboratory Method for Studying Water Coalescence of Aviation Fuel SAE* ***Technical Paper Series No. 881534*** (October 1988)

1.4 Conclusions/Recommendations

1.4.1 Conclusion

The findings of this study indicate that the customary minimum D3948 MSEP of 70 can be relaxed when a drop in rating is ***specifically due to the addition of Stadis 450***. The data indicate that Stadis 450 will not disarm coalescers even though MSEP may be low. However, there is a need to maintain control over chance contamination which may occur during fuel handling and distribution which could have a deleterious effect on coalescence.

1.4.2 Recommendations

- Permit re-doping of aviation turbine fuel with Stadis 450 to maintain conductivity within specification provided that depression in MSEP is known to have been caused by Stadis 450. In practices or specifications where a minimum MSEP is required, the minimum can be waived provided the absence of contamination downstream of the re-doping can be assured.

- Further work should be done to develop a valid test for measuring contaminants which deactivate coalescers whether or not Stadis 450 is present. This may require reinterpretation of MSEP, modification of the MSEP test, or development of a new test. (ASTM Committee D-2, Section J-10 currently is pursuing MSEP modifications and new methods with some encouraging results.)

2. Introduction

2.1 Background

It has long been accepted that there can be surface active components in aviation turbine fuel which can have deleterious effects on filter/coalescer performance. Bert and Porter[5] indicated that sulphonates and napthenates were the principal constituents of these surface active materials. Orrell[6] indicated that phenols, carboxylic acids, sulphonic acids, and amines were also retained on coalescer elements. High concentration of these surfactant compounds could lead to several deleterious effects:

- Deactivation of filter/coalescers, i.e., water no longer coalesces as it passes through the filter/coalescer;
- Dispersion of dirt causing increased pressure drop and solids transmission through the filter/coalescers;
- Interaction with approved additives in turbine fuel.

As a result, the aviation industry looked at several techniques for measuring the amount of surfactants present and of controlling the amount permitted. Of these techniques, the Water Separation Index (WSI) and its later modifications, viz., the Water Separation Index Modified (WSIM)[7], Minisonic Separometer Surfactants (MSS)[8], and Microseparometer Rating (MSEP)[9], have become accepted industry test methods to measure the presence of surfactants in aviation fuel.

Having developed a tool for measuring surfactants in turbine fuels, significant work was performed to determine if this measurement could be related to coalescer deactivation and to establishing guidelines for maximum acceptable limits of surfactants in fuels. Some of the significant work is reviewed below.

During this time, static electrical discharges during fuelling which could potentially cause fires, and damage to equipment became a concern. As a result, two additives were developed, viz. Stadis 450 and ASA-3, which increased the conductivity of the fuel and hence minimized the charge relaxation time. Use of these additives became commonly used in commercial and military systems. Thus, when some undesirable fuel- additive interaction occurred, the user could readily switch to the other static dissipater product. Recently, the manufacture and sale of ASA-3 was discontinued. Thus, any unusual interaction effect with Stadis 450-fuel has to be investigated and proven to be not harmful.

2.1.1 Coalescer Deactivation Due to Surfactants in Turbine Fuel

Early work by the Coordinating Research Council (CRC) concentrated on modifying the WSI test to be more sensitive to surfactants. This led to the development of the WSIM procedure[10]. This work was

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[5]Bert, J. A., H. R. Porter **Proc. American Petroleum Institute** <u>43</u> 165 (1965)

[6]Orrell, L. **Filtration and Separation** 301 (July/August 1981)

[7]American Society of Testing Materials *Annual Book of ASTM Standards Vol. 5.02* ***D2550-85*** (1985)

Note: D2550 was discontinued in 1991.

[8]American Society of Testing Materials *Annual Book of ASTM Standards Vol. 5.03* ***D3602***

[9]American Society of Testing Materials *Annual Book of ASTM Standards Vol. 5.03* ***D3948***

[10]Coordinating Research Council *Development of a Research Technique for Assessing the Water Separation Characteristics of Fuels and Fuel-Additive Combinations* CRC Report No. 358 (Feb. 1962)

paralleled by work in the military[11] examining whether the WSIM procedure could predict coalescer performance with large and full scale systems. Using the same fuels and additives as the CRC, Southwest Research Institute and the US Air Force Aeronautical Systems Division showed that there was a relation between coalescer performance and WSIM. They reported coalescer performance as being satisfactory, marginal, or unsatisfactory for a number of filter/coalescer systems. Figure 2.1 summarizes this data showing the percentage of satisfactory results obtained at a given WSIM. The results clearly show that the higher the WSIM rating the better the chances that the coalescer can coalesce water effectively. In addition to this work, the US Air force had service experience where a fuel with a WSIM of 46-56 gave unsatisfactory coalescer performance. When the refinery changed its practices to provide high WSIM fuels, the coalescer performance improved dramatically.

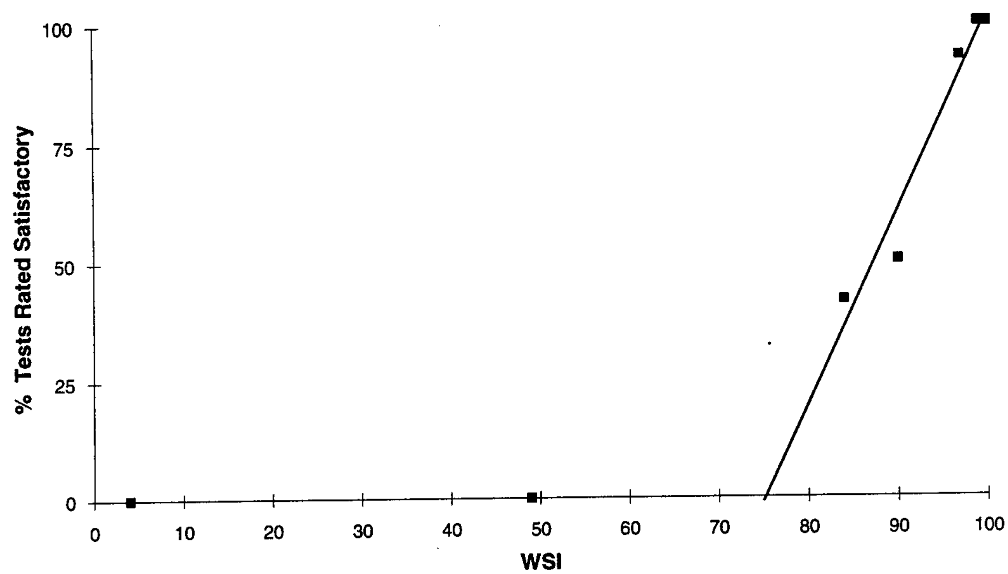

Figure 2.1 -- Relationship Between Coalescer Performance and WSIM Readings (Source: Rogers et al[12])

This work as well as field experience seemed to form the basis for setting a minimum WSIM rating of fuel without static dissipater or corrosion inhibitor additives at 90 for commercial operation. When the MSS procedure was developed for field use, it was accepted that some reduction in WSIM would be a natural outcome of transporting fuel. A WSIM value of 85 minimum was selected to allow for some degradation during transportation[13].

The effect of additives on WSIM and coalescer performance was studied as early as 1968[14]. Figure 2.2 shows that there was a fairly good relationship between effluent water concentration and WSIM

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[11]Rogers, J.D., J. A. Krynitsky, A.V. Churchill *SAE Trans.* ***71*** 281 (1963)

[12]ibid (Summary of Table 6)

[13]Bill Dukek *personnal communication*

[14] Bitten, J.F. *Study of Aviation Fuel Filter/Separators* Report No. IITRI-C6088-8 (April 1968)

for a wide variety of contaminants/additives[15]. These experiments were done using a coalescer cell and influent water concentration of 10,000 ppm which probably accounts for the high water concentration in the effluent. Bidden subsequently showed that single element tests related well to the coalescer cell in a limited number of experiments.

In another study, Gardner[16] conducted single element tests adding 100 ppm water for one hour followed by fuel only for another hour using Canadian military elements. He studied a number of additives and contaminants. A summary of this data is given in Figure 2.3. Gardner assumed that a 5 ppm increase in the effluent water content was unsatisfactory when a corrosion inhibitor (CI), static dissipater additive (SDA), or sulphonate was added. Using this criterion, Gardner concluded that a WSIM of 75 could be tolerated without undue effect on the performance or life of the coalescer. The work of Gardner, in addition to other studies and experience, led to the minimum WSIM rating of 70 in many specifications where additives are present.

More recent work by Swift[17] measured the effect of MSEP and effluent water concentration using the Exxon Coalescence Test. This work was subsequently verified using a single element test. The results are shown in Figure 2.4. Corrosion inhibitors (CI), anti-oxidants (AO), DiEGME, Petronate HL, ASA-3 and Stadis 450 were studied The inlet water concentration ranged from 100 ppm to 1000 ppm. These results were later verified in single element tests. The conclusion drawn is that there is a relatively good relationship between MSEP and effluent water concentration. The exceptions were ASA-3 which gave relatively high MSEP but poor coalescer performance (at high concentrations of ASA-3), Petronate HL gave similar results. Stadis 450, on the other hand, gave good coalescer performance but abnormally low MSEP.

Based on these results, field experience, and other work, several turbine fuel specifications require a minimum MSEP (WSIM) level. In most specifications where MSEP is used, a minimum MSEP of 85 is required for an unadditized fuel, or fuel containing only anti-oxidants. Recognizing that approved additives can reduce the MSEP value without affecting coalescer performance, the MSEP minimum value normally is reduced to 70 when corrosion inhibitors/lubricity improvers, anti-icing additives are used or when static dissipaters are used. A brief summary of the specifications addressing MSEP is given in Appendix A.

2.1.2 The Effect of Stadis 450 on WSIM and Conductivity

Normally, Stadis 450 increases the conductivity of turbine fuels without any serious side effects. For some, primarily non-hydrotreated, fuels, interactions between static dissipater additives and the fuel occur which cause a deterioration in conductivity with time. While such deterioration has been reported for both ASA-3 and Stadis 450, the MSEP often recovered when the conductivity deteriorated for ASA-3 while the MSEP with Stadis 450 remained depressed while the conductivity deteriorated. This combined with the fact that the MSEP drop with Stadis 450 often is greater than that occurring with ASA-3 can cause a problem with re-doping the fuel to provide the desired conductivity level. In these cases, the re-doping of the fuel with Stadis 450 would result in MSEP lower than 70.

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[15] RP-2 and AFA-1 -- a mixture of 25% Octyl phosphate esters, 55% Octylamines + octyl alcohols, 20% hydrocarbon

NaSul EDS -- 50% ethylenediamine dinonyl napthalene sulphonate in mineral seal oil

Santolene C -- 50% dilinoleic acid; ~ 0.35% phosphorous in hydrocarbon solvent

[16] Gardner, L. *Relationship Between WSIM ratings and Filter/Separator Performance* Paper Presented to SAE National Air Transportation Meeting, April 20-23, Paper No. 700279 (1970)

[17] Swift, S. T. *Development of a Laboratory Method for Studying Water Coalescence of Aviation Fuel **SAE Technical Paper 881534*** (1988)

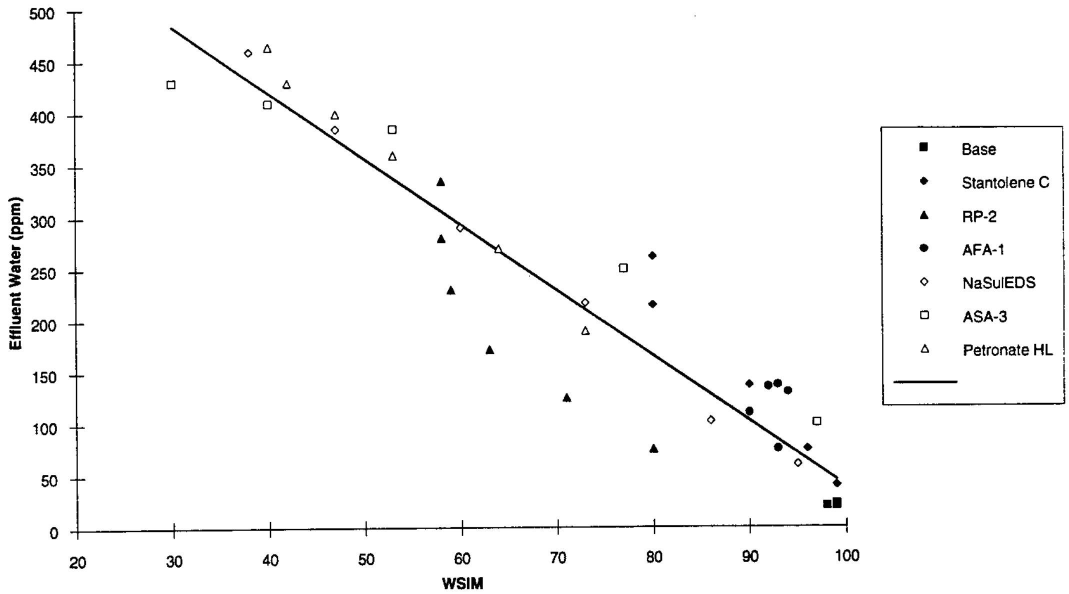

Figure 2.2 -- Effect of WSIM on Coalescence for a Wide Variety of Additives (Source: Bitten[18])

While the MSEP is often significantly depressed by Stadis 450, there is no evidence that this causes any serious deterioration in coalescer performance. If MSEP resulting from addition of Stadis 450 does not correlate with coalescer performance, then re-doping would be possible without regard to MSEP. Establishing such a database of experience is the purpose of this report.

[18]ibid

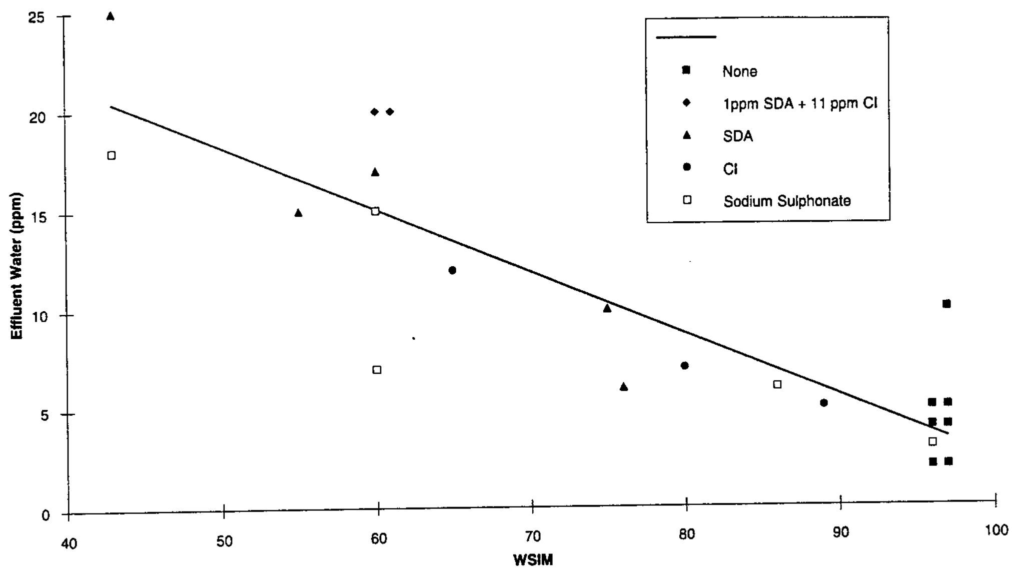

Figure 2.3 -- Effect Additives on Coalescer Performance (Source:Gardner[19])

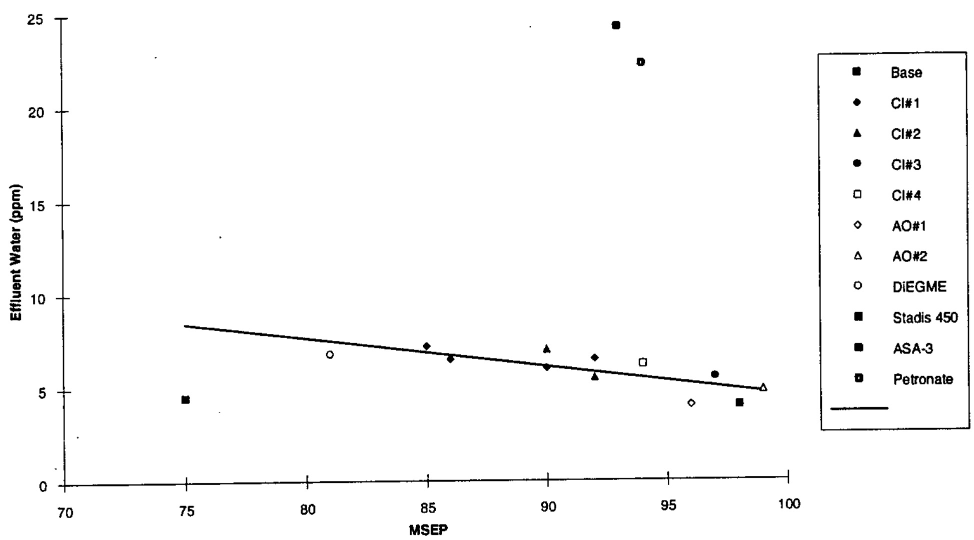

Figure 2.4 -- Recent Study of Effect of MSEP on Coalescence (Source: Swift[20])

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[19]ibid

[20]ibid

3. Technical Basis

3.1 Field Experience

3.1.1 Historical Observation

Stadis 450 has been used for over 15 years. Except for one well documented case where Stadis 450 reacted with non-hydrotreated fuels to form a precipitate which deactivated coalescers, it has been generally accepted that Stadis 450 does not affect coalescer performance adversely even though MSEP is somewhat lower than with ASA-3 additized fuels. This is based on over 15 years of experience in military and commercial use. The recent re-formulation of Stadis 450 is believed to have solved the problem of coalescer deactivation by precipitate formation.

3.1.2 United States Air Force Service Tests[21]

The United States Air Force conducted a service test of two fuel conductivity additives (ASA-3 and Stadis 450) during the period April 1977 to May 1979. This work was carried out prior to establishing a mandatory requirement to add static dissipater additive to JP-4 fuel in MIL-T-5624, Military Specification for Turbine Fuel, Aviation, Grades JP-4, JP-5, and JP-5/JP-8. Areas investigated included additive handling and injection, meeting conductivity targets and retention of conductivity, and effects on water separation.

Water separation properties were evaluated thoroughly. Laboratory tests included the ASTM D2550 (WSIM), D3602 (MSS), and a test which was a prototype for the current D3948 (MSEP) test. The effects of adding conductivity additives to fuels already containing fuel system icing inhibitor and corrosion inhibitor/lubricity additive were determined, and most importantly, a series of single element tests were carried out at six airbases where throughput of fuel containing FSII, corrosion inhibitor, and conductivity additive averaged 3,700,000 gallons through 300 to 600 gallon per minute vessels.

General conclusions drawn from this report are:

- Single element tests were satisfactory for fuels which had D2550 WSIM below 70 as a consequence of adding both corrosion inhibitor and conductivity improver.
- WSIM at airbases during the study period followed a bimodal distribution, with sizable populations between 45-60 and 71-85.
- The effect of conductivity additive on the WSIM rating of fuels already containing corrosion inhibitor and FSII also tended to fall into two population groups.
- When WSIM values less than 70 are obtained as a consequence of adding corrosion inhibitor and/or conductivity additive, satisfactory water separation is achieved. This conclusion presumes that base fuel WSIM is a reasonable value (such as 85 minimum as required in DEFSTAN 91-91) which is generally needed to provide a minimum value of 70 when all military fuel additives are present except conductivity additive. Data tend to support a similar

21 Martel, Charles, Frank Morse *Service Test of Two Fuel Conductivity Additives* Technical Report AFWAL-TR-80-2051 (May 1980)

conclusion for the MSEP test, but less definitively because the prototype MSEP test was not carried out at all locations.

Single element tests were carried out using an initial emulsified water concentration of 0.5%. However, the report notes that during the test emphasis was placed on the state of initial coalescence. Coalescers used were qualified to MIL-F-8901. In most cases new elements were installed at the beginning of the test program. Element in-service time varied from 4 to 14 months. Coalescers were tested at six of eight bases in the study program. Figure 3.1 shows the range of WSIM obtained. A significant number were below 70. Table 3.1 indicates that performance was satisfactory at all the air force bases for both Stadis 450 & ASA-3 containing fuels.

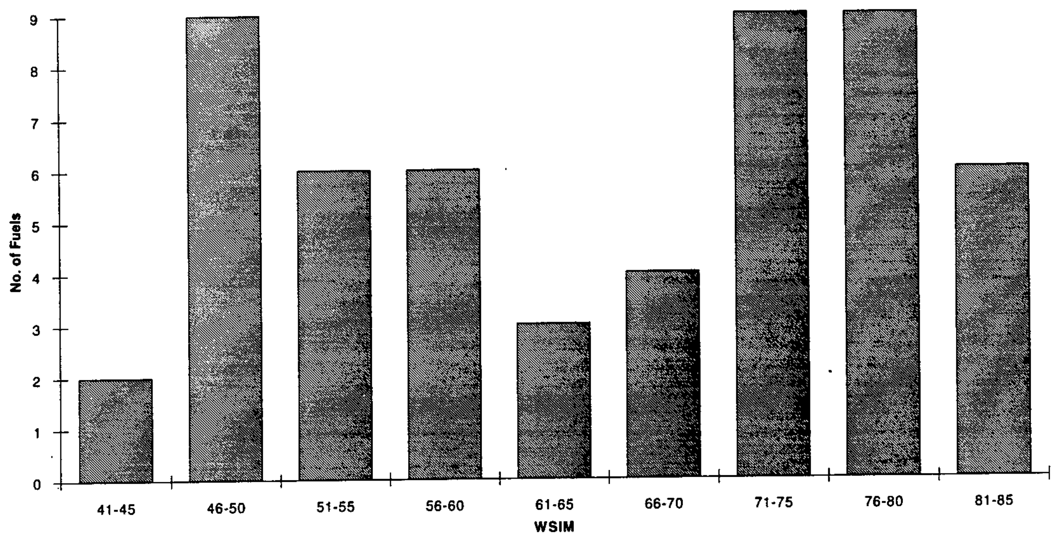

Figure 3.1 -- Range of WSIM Found in Military Fuels

Table 3.1 -- Coalescer Performance at Various Military Bases

AF Base	Element Installed Date	Start Date Additive	Date of Test	Cond. Add. Used	F/S Location	ThruPut X 1000 Gallons	Dif. Pressure (PSI)	Coalescence Performance
Griffiss	May 1977	2 May 77	25 Oct 77	S-450	Hyd PH 2	600	1.0	Satisfactory
	March 1975				Hyd PH 3	900	2.5	Satisfactory
Myrtle	May 1977	14 June	31 Oct 77	ASA-3	Fillstand 1	1,000	5.0	Satisfactory
Beach	June 1977	77			Fillstand 3	1,800	5.0	Satisfactory
Carswell	July 1977	20 June	23 Feb 78	S-450	Hyd PH	1,880	20	Satisfactory
	June 1977	77		&	Fillstand	9,200	12	Satisfactory
	Aug 1975			ASA-3	R-5 Ref.	4,900	7	Satisfactory
Travis	July 1977	18 July 77	20 Mar 78	ASA-3	Hyd PH C	3,700	17	Satisfactory
	Oct 1976				Hyd PH D	1,300	6	Satisfactory
	March 1976				Hyd PH E	2,200	16	Marginal
	Nov 1976				Rec Line B	7,500	5	Satisfactory
Mt Home	Oct 1977	19 Oct 77	23 Mar 78	ASA-3	PH 1317	6,000	4	Satisfactory
	May 1975				PH 265	Unknown	1.5	Satisfactory
	Sept 1975				R-9 Ref.	750	6	Satisfactory
Davis-	Nov 1977	25 July 77	14 Sept	S-450	Hyd PH J-3	7,000	6	Satisfactory
Monthan	Nov 1977		78			7,000	8	Satisfactory

3.2 Experimental Verification

Swift examined a number of additives, surfactants, and static dissipater additives using a small scale coalescence tester. He later verified the work using a full scale single element test rig. The results are shown in Figure 2.4. As seen from this figure the MSEP results seem to correlate quite well with effluent water concentration for most additives. Petronate HL and ASA-3 showed much higher effluent water concentrations than the correlation would predict. The fuel containing Stadis 450 showed much lower effluent water ratings than the correlation would have predicted. The actual effluent water concentration was 4.5 ppm water at a MSEP of 75. The correlation would predict an effluent water concentration of 8.5 ppm for the 75 MSEP.

To examine the effect of Stadis 450 vs. ASA-3 on coalescence in modern filter/separators, a search was made of various API 1581[22] qualification test reports, military studies, and test data from vendors. The results of these studies as well as a listing of sources, and a brief description of the test are given in Appendix B. A summary of the results follows:

- MSEP after the addition of Stadis 450 does not seem to correlate with the concentration of water in the effluent. Figure 3.2 shows the results from a variety of tests using fuels with Stadis 450 only; Stadis 450 and Hitec 580; and Stadis 450, Hitec 580 and FSII. (The data at 98 MSEP is for unadditized fuel). MSEP ranged from 31 to 98. There was no discernible difference in the results. The major factors affecting water in the effluent are the manufacturer and type of coalescer.

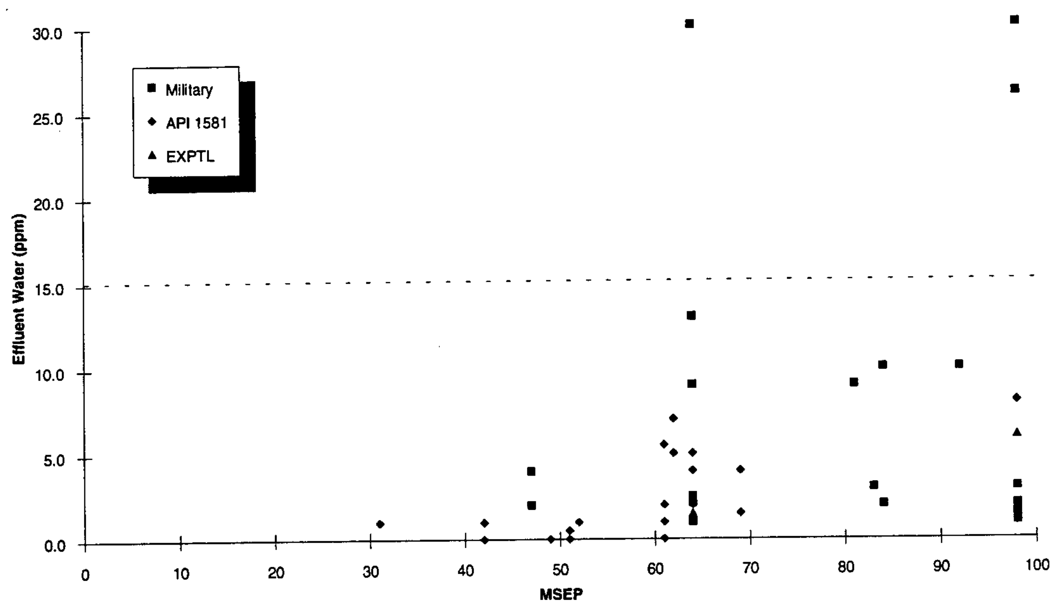

Figure 3.2 -- The Effect of Stadis 450 on Effluent Water

[22]American Petroleum Institute, *Specifications and Qualification Procedures for Aviation Jet Fuel Filter/Separators* API Publication 1581, 3rd Edition, May 1989

- Figure 3.3 narrows the data to API 1581 3rd Edition qualified elements. Most tests were done in accordance to the Test Series 1, 2, 3 procedures for water addition. The specific tests are noted in Appendix B. In addition data from qualification tests where ASA-3 was used have been added to the figure. Again, the data indicated that there is no relationship of water in the effluent to MSEP resulting from the presence of Stadis 450 or ASA-3.

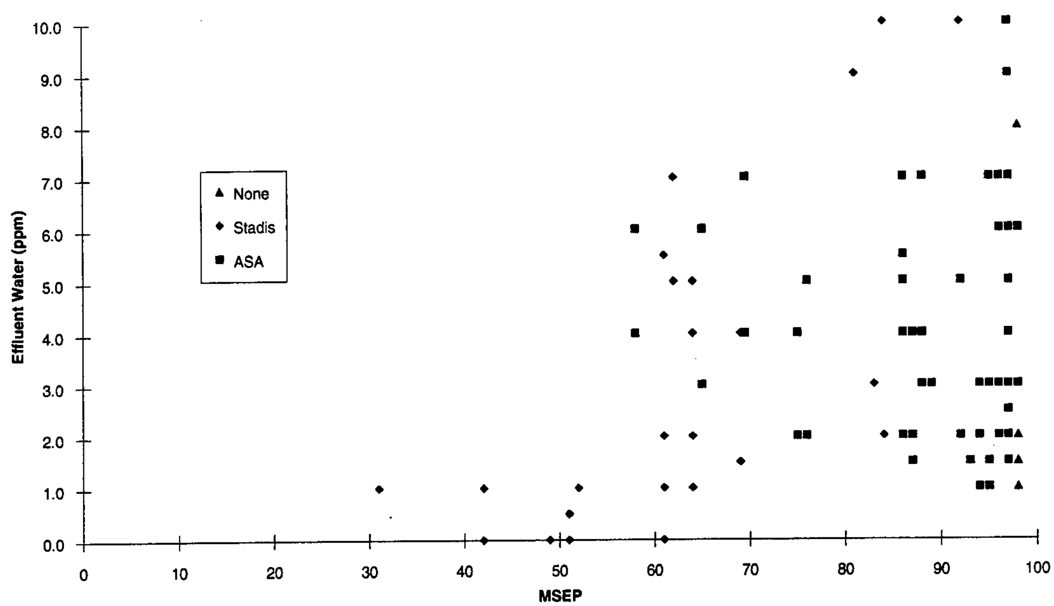

Figure 3.3 -- Effect of Stadis 450 or ASA-3 on API 3rd Edition Qualified Elements

An alternate way to examine the data is to look at the distribution of effluent water concentration for each additive. The data given in Appendix B for API 1581 qualified elements had markedly different ranges of MSEP values. As shown in Figure 3.4, fuel additized with Stadis 450 has a lower value of MSEP than fuels additized with ASA-3. For fuels additized with ASA-3, the mean MSEP was 88.7 with a standard deviation of 10.4. For fuels additized with Stadis 450, the mean MSEP was 63 with a standard deviation of 13.8. Even though the average MSEP for fuels containing Stadis 450 was 25.7 points lower than for fuels containing ASA-3, the difference in effluent water concentration did not differ significantly. Figure 3.5 shows the effluent water for fuel containing Stadis 450 , fuel containing ASA-3, and a calculated normal distribution when all the effluent water data are considered. The average water concentration in the effluent of Stadis 450 containing fuels was 2.9 ppm with a standard deviation of 2.8 ppm. For ASA-3 containing fuels, the average water concentration in the effluent was 3.9 ppm with a standard deviation of 2.2 ppm. When fuels containing Stadis 450 and ASA-3 are considered collectively, the average water concentration in the effluent is 3.5 ppm with a standard deviation of 2.5 ppm. Thus, one can conclude that MSEP generated by static dissipater additive do not have a significant effect on the concentration of water in the effluent fuel after passing through an API 1581 qualified filter/coalescer vessel. The data in Appendix B used in this analysis included fuels which contained a corrosion inhibitor (Hitec 580) as well as red iron oxide in some cases. This gives some confidence that this study would be valid over the range of conditions typically found in the field.

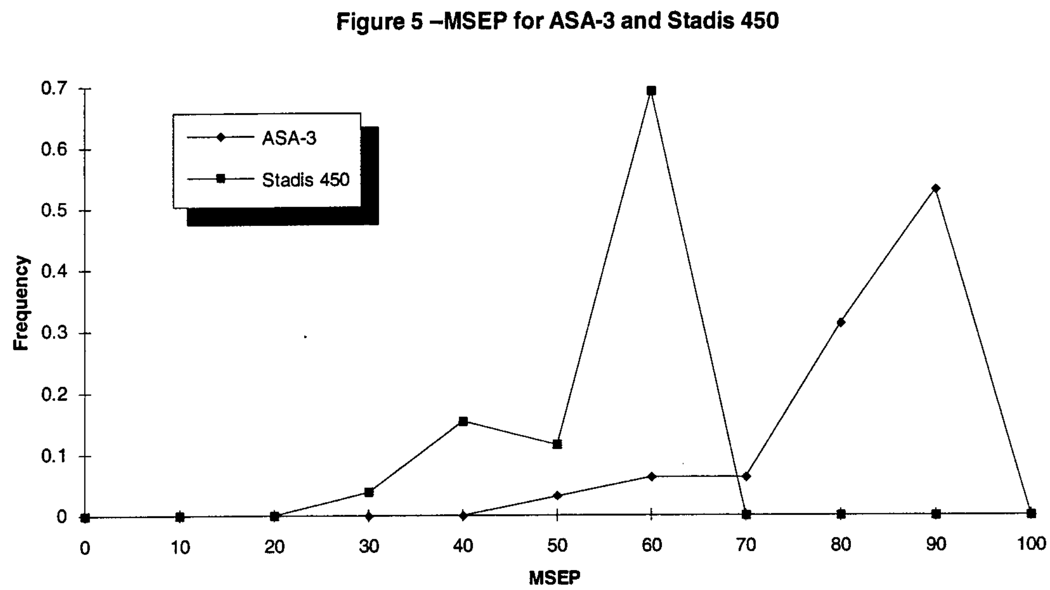

Figure 3.4 - The Range of MSEP for Stadis 450 and ASA-3 Additized Fuels Studied

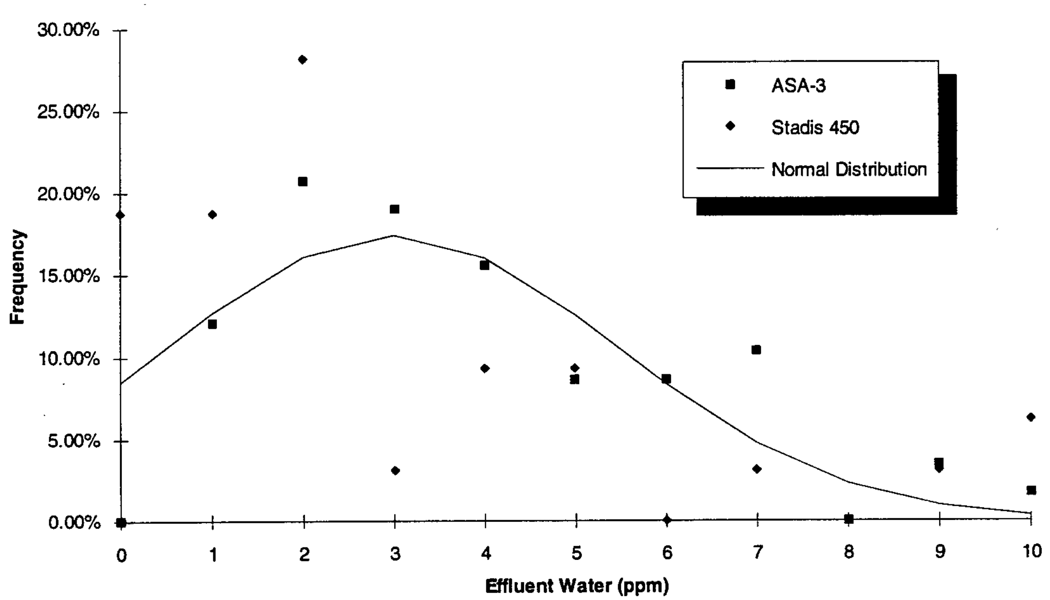

Figure 3.5 -- Distribution of Water in the Effluent for Stadis 450 and ASA-3 Containing Fuels Studied

4. Conclusions/Recommendations

4.1 Conclusion

The findings of this study indicate that the customary minimum D3948 MSEP of 70 can be relaxed when a drop in rating is ***specifically due to the addition of Stadis 450***. The data indicate that Stadis 450 will not disarm coalescers even though MSEP may be low. However, there is a need to maintain control over chance contamination which may occur during fuel handling and distribution which could have a deleterious effect on coalescence.

4.2 Recommendations

- Permit re-doping of aviation turbine fuel with Stadis 450 to maintain conductivity within specification provided that depression in MSEP is known to have been caused by Stadis 450. In practices or specifications where a minimum MSEP is required, the minimum can be waived provided the absence of contamination downstream of the re-doping can be assured.

  For example, in the case of the current CAN/CGSB 2.3 Specification for Aviation Turbine Fuel, Kerosene Type, a minimum MSEP of 70 and a conductivity of 50-450 pS/m is required at the time of manufacture and at all points in the distribution system. For this case, a reasonable protocol to provide relief for non-hydrotreated fuels without significantly changing the intent of the specification may be as follows:

  1. After the first addition of Stadis 450, the fuel shall have a conductivity of 50 to 450 pS/m and a minimum MSEP of 70.
  2. In the event that the fuel must be re-doped with Stadis 450 to increase conductivity, then a minimum limit of 70 MSEP will apply before re-doping.
  3. After re-doping with Stadis 450, the MSEP shall not apply provided that the fuel subsequently enters dedicated transportation to the airport or in airport storage.
  4. Maximum concentration limits of Stadis 450 which can be added shall be governed by those stated in ASTM D1655 and/or DEFSTAN 91-91.

- Further work should be done to develop a valid test for measuring contaminants which deactivate coalescers whether or not Stadis 450 is present. This may require reinterpretation of MSEP, modification of the MSEP test, or development of a new test. (ASTM Committee D-2, Section J-10 currently is pursuing MSEP modifications and new methods with some encouraging results.)

Appendix A -- Summary of Specifications Requiring Minimum MSEP

Table A.1 Specifications Listing MSEP/WSIM as Requirement[23]

Specification	MSEP (min)	Procedure	Notes
Joint Fueling System Checklist		D3948	a. Limit at point of manufacture with only anti-oxidant additive in the fuel. In the event of either SDA, FSII, or CI/LI being present singly at the point of manufacture, a MSEP of 70 or better is consistent with 85 for the untreated product. When SDA and CI/LI are present together no meaningful MSEP can be obtained. This requirement applies only on production and failure to comply at a later stage in the distribution shall be a cause for investigation but not necessarily for rejection.
+ W/ SDA	70		
+ W/O SDA	85[a]		
Colonial Pipeline Grade 54 Fungible Aviation Kerosene (w/o SDA or corrosion inhibitor)		D2550, D3948, D3602	
+ at Origin	85		
+ at Delivery	75		
Buckeye Pipeline Grade 182 Fungible Aviation 1K Kerosene (w/o SDA or corrosion inhibitor)		D2550, D3948, D3602	
+ at origin	Report		
Explorer Pipeline Code 51 Fungible Aviation Turbine Fuel - Jet A1 (w/o SDA or corrosion inhibitor)		D2550, D3948, D3602	
+ at Origin	85		

[23]Exxon Company International, *Jet Fuel Specifications* 1995 Edition

Table A.1 cont

Specification	MSEP (min)	Procedure	Notes
USAF Mil-T-5624 P		D2550, D3948	b. Limits with all additives included except corrosion inhibitor/lubricity improver and static dissipater. Minimum reduced to 70 minimum with all additives included except static dissipater.
+ JP-4 Wide-Cut	85[b]		
+ JP-5 Kerosene	85[c]		c. Limits with all additives included except corrosion inhibitor/lubricity improver and static dissipater. Other options for JP-5 and JP-5/JP8 ST are (a) 90 minimum with only anti-oxidant and metal deactivator (if used) present, (b) 80 minimum with all additives present except icing inhibitor, (c) 70 minimum with all additives present. Regardless of option selected, report WSIM on hand blend JP-5/JP8 ST with additives present.
+ JP-5/JP8 ST Special Test Fuel	85[c]		
USAF MIL-T-38219B AMD-1 JP-7 Low Volatility	85	D2550	
USAF MIL-T-83133D JP-8 Kerosene	85[d]	D2550	d. Limits with all additives included except corrosion inhibitor/lubricity improver and static dissipater. Minimum reduced to 70 minimum with all additives included except static dissipater.
Australia Civil Jet A-1 Kerosene	70[e]	D2550, D3948	e. If sample contains sediment or insoluble matter, allow to settle and decant clear fuel before testing. Do not prefilter sample.
Australia Department of Defense DEF(AUST) 5208 AVTUR Kerosene	85[f,g]	D2550, D3948	f. Limit applies only to production or establishment of main batch prior to addition of static dissipater. Failure to comply in later stages of distribution shall be cause for investigation but not rejection in the first instance. g. WSIM- 70 minimum with static dissipater in the fuel.
Brazil, National Council of Petroleum QAV-1 Kerosene		D2550, D3948	h. Stated limits apply only at the point of manufacture. Failure to comply at later stages of distribution shall be cause for investigation but not rejection in the first instance. WSIM for fuel containing both static dissipater and corrosion/lubricity additives is not limited, but fuel must have a WSIM of 85 minimum prior to addition of both additives and 70 minimum with only the static dissipater additive added but before the addition of the corrosion inhibitor.
+ without ASA	85[h]		
+ with ASA	70[h]		
Canada, CAN/CGSB 3.23-93 Jet A1/A Kerosene	70[i]	D3948	i. Limit applies to fuel with all additives except corrosion inhibitor and anti-icing additive. When fuel contains these additives no WSIM limit shall apply.
Canada, CAN/CGSB 3.22-93 Jet B	70[i]	D3948	
Canada, 3-GP-24 Mb High Flash Kerosene	85[j]	D3948	j. Applicable to fuel containing all additives except static dissipater and corrosion inhibitor.

Table A.1 cont

Specification	MSEP (min)	Procedure	Notes
Colombia, ICONTEC 1899 Turbo Combustible Para Aviation		D2550	k. This requirement is being controlled at the refinery on sample taken after 24 hours of settling time.
+ Jet A	85[k]		
+ Jet B	85[k]		
Japan, Petroleum Association of Japan, Joint Fueling System Checklist Issue 10 - Amendment 1, Kerosene		D3948, JIS K2276	
+ w/static dissipater additive	70		
+ w/o static dissipater additive	85		
Japan, SDF DSP K2206C		D3948, JIS K2276	l. The minimum water separation index rating for JP-4 should be 85 with all additives except corrosion inhibitor/lubricity improver additive and static dissipater additive present, or 70 with all additives present except for static dissipater.
+ JP-4 Wide-Cut	l		
+ JP-5 High Flash Kero	70		
Spain, INTA 15 13 17N Kerosene	85[m]	D2550, INTA 15.02 57B/15 06 25	m. Limit of 85 applies only to fuel containing anti-oxidant additive. The limit is 70 minimum, when the fuel contains static dissipater or corrosion inhibitor/lubricity improver. When both static dissipater and corrosion inhibitor/lubricity improver are present, no limit is applied.
Sweden, Swedish Defense Material Administration, FSD-8607, FLYGFOTOGEN 75 Kerosene	70[n]	D3948	n. Prior to addition of static dissipater additive and corrosion inhibitor. With lubricity improver and without static dissipater additive minimum WSIM is 70.
United Kingdom, DERD 2486 (Issue 9) Amend. 1 AVTAG Wide-Cut	85[o]	D3948	o. Limit at point of manufacture with only anti-oxidant additive in the fuel. In the event of either SDA, FSII, or CI/LI being present singly at the point of manufacture, a MSEP of 70 or better is consistent with 85 for the untreated product. When SDA and CI/LI are present together no meaningful MSEP can be obtained. This requirement applies only on production and failure to comply at a later stage in the distribution shall be a cause for investigation but not necessarily for rejection.

Table A.1 cont

Specification	MSEP (min)	Procedure	Notes
United Kingdom, DEF STAN 91-91/1 AVTUR Kerosene	85[o]	D3948	
United Kingdom, DERD 2498 (Issue 7) Amend. 1 AVCAT High Flash Kerosene	85[p]	D3948	p. With corrosion inhibitor WSIM=70 min.
Venzuela, COVENIN 1023-92 Jet A-1 Kerosene		COVENIN 1136	
+w/o static dissipater	85		
+ w/ static dissipater	70		
+ w/ corrosion inhibitor			
Venzuela, COVENIN 1023-92 JP-5 Kerosene		COVENIN 1136	
+w/o static dissipater			
+ w/ static dissipater	70		
+ w/ corrosion inhibitor	85		

Appendix B -- Database of Fuels and Conditions Used

Table B-1 -- References for Data

#	Reference
1	Russell, E.C. *Test and Evaluation of Military Standard Dimension and American Petroleum Institute Dimension Elements in Accordance with Draft Military Specification MIL-F-8901F* Contract No. DAAK70-92-D-004 U.S. Army (May 1995)
2	Test Report No. 583-95: *API 1581 Qualification Testing of Velcon Vertical Filter/Separator Vessel VV-4256 to Group II, Class B Performance Requirements at 2500 USGPM* Velcon Filters Inc August 1995
3	Data provided by Facet International letter to E. Matulevicius from Robert Anderson 9/11/95
4	Velcon Test 2/11/94
5	Test Report No. 560-92: *API 1581 Qualification Testing Model V-1633 Filter/Separator with 2 Ea. I-63387TB Coalescers and 1 ea. SO-629C Separator Group II, Class B, 158 USGPM* Velcon Filters Inc. Dec. 1992
6	Test Report No. 527-90: *API 1581 Qualification Testing Model HV-1633 Filter/Separator with 3 Ea. I-63385TB Coalescers and 1 ea. SO-436C Separator Group II, Class B, at 241 USGPM* Velcon Filters Inc. May 1990
7	*Qualification Tests FW7, Group II, Class B VB 12/92 API Bulletin 1581, 3rd Edition Specification and Qualification Procedures Aviation Jet Fuel Filter Separators* Faudi Feinbau GmbH 1992
8	*Qualification Tests FW7-T, Group II, Class C VB 13/92 API Bulletin 1581, 3rd Edition Specification and Qualification Procedures Aviation Jet Fuel Filter Separators* Faudi Feinbau GmbH 1992
9	Test Report No. 555-92: *API 1581 Qualification Testing Model VV-1033 Filter/Separator with 1 Ea. I-63387TB Coalescers and 1 ea. SI-818 Separator Group II, Class B, 100 USGPM* Velcon Filters Inc. Sept. 1992
10	Qualification Test Report No. 6-1101A-88 Facet/Quantek *Vertical Filter/Separators in Accordance with API 1581, Third Edition, May 1989 as Group II Class B Units for a Range From 600 GPM Through 4800 GPM* Quantek Feb 16, 1990
11	*Qualification Testing on Horizontal "S" Type Filter Separators:- HCS 6S12F-7A28-3, HCS 1S5F-1A14-3, Tested in Accordance with API 1581 Group II Class C* Facet IFS 2607 (1993)
12	*Qualification Testing on Horizontal Filter Separators:- HCS 2S48F-7A56-3SB, HCS 1S15F-2A29-3SB, HCS 1S4F-1A15-3SB, Tested in Accordance with API 1581 Group II Class C* Facet IFS 2468 (1992)
13	*Qualification Testing on Vertical Filter Separators:- VCS 1 S6F 1A14-3 Test Flow 32 USGPM, VCS 48F 7A46-3 Test Flow 750 USGPM, Tested in Accordance with API 1581 Group II Class A* Facet IFS 2499 (1991)
14	*Qualification Testing on Horizontal Type Filter Separators:- HCS -C-333-1436, HCS -C-114-1404, Tested in Accordance with API 1581 Group II Class B* Facet IFS 2775 (1994)
15	Sprenger, Greg, API 1581 MSEP Vs Water Removal, Stadis 450 letter to E. Matulevicius (Velcon) 6/29/95

Table B.2 -- Stadis 450 Data

Ref	Element	MSEP	Stadis 450 Conc. (ppm)	Stadis 450 k (pS/m)	Additives	Water Influent (%)	Water Effluent (ppm)	Comments
1	A	98	0	10	None	0.01	1.5	DOD Element from manufacturer A; Note: All DOD Elements 3.75" OD and 20" Long
1	B	98	0	10	None	0.01	1.0	DOD Element from manufacturer B
1	C	98	0	10	None	0.01	3.0	DOD Element from manufacturer C
1	D	98	0	10	None	0.01	30.0	DOD Element from manufacturer D; Actual Effluent greater than 30 ppm
1	E	98	0	10	None	0.01	2.0	DOD Element from manufacturer E
1	F	98	0	10	None	0.01	6.0	Experimental Element from manufacturer F
1	G	98	0	10	None	0.01	1.5	API Element from Manufacturer G; Note All API elements 6" OD and 11" Long
1	H	98	0	10	None	0.01	2.0	API Element from Manufacturer H
1	J	98	0	10	None	0.01	1.0	API Element from Manufacturer J
1	A	98	0	10	None	1	3.0	DOD Element from manufacturer A
1	B	98	0	10	None	1	1.0	DOD Element from manufacturer B
1	C	98	0	10	None	1	1.0	DOD Element from manufacturer C
1	D	98	0	10	None	1	26.0	DOD Element from manufacturer D
1	E	98	0	10	None	1	1.5	DOD Element from manufacturer E
1	F	98	0	10	None	1	1.5	Experimental Element from manufacturer F; Element Rupture
1	G	98	0	10	None	1	1.5	API Element from Manufacturer G; Note All API elements 6" OD and 11" Long
1	H	98	0	10	None	1	8.0	API Element from Manufacturer H
1	J	98	0	10	None	1	1.0	API Element from Manufacturer J
1	A	64		520	23 mg/liter Hitec 580 & 0.2% DiEGME	0.01	9.0	DOD Element from manufacturer A; Note: All DOD Elements 3.75" OD and 20" Long; Stadis 450 added to achieve 150pS/m<k<600 pS/m for all tests below
1	B	64		520	23 mg/liter Hitec 580 & 0.2% DiEGME	0.01	2.1	DOD Element from manufacturer B
1	C	64		520	23 mg/liter Hitec 580 & 0.2% DiEGME	0.01	2.5	DOD Element from manufacturer C
1	D	64		520	23 mg/liter Hitec 580 & 0.2% DiEGME	0.01	30.0	DOD Element from manufacturer D; Actual Effluent greater than 30 ppm
1	E	64		520	23 mg/liter Hitec 580 & 0.2% DiEGME	0.01	1.0	DOD Element from manufacturer E
1	G	64		520	23 mg/liter Hitec 580 & 0.2% DiEGME	0.01	2.0	API Element from Manufacturer G
1	H	64		520	23 mg/liter Hitec 580 & 0.2% DiEGME	0.01	2.0	API Element from Manufacturer H
1	J	64		520	23 mg/liter Hitec 580 & 0.2% DiEGME	0.01	2.0	API Element from Manufacturer J
1	A	64		520	23 mg/liter Hitec 580 & 0.2% DiEGME	1	30.0	DOD Element from manufacturer A
1	B	64		520	23 mg/liter Hitec 580 & 0.2% DiEGME	1	30.0	DOD Element from manufacturer B
1	C	64		520	23 mg/liter Hitec 580 & 0.2% DiEGME	1		DOD Element from manufacturer C; element failure
1	D	64		520	23 mg/liter Hitec 580 & 0.2% DiEGME	1	30.0	DOD Element from manufacturer D
1	E	64		520	23 mg/liter Hitec 580 & 0.2% DiEGME	1	13.0	DOD Element from manufacturer E
1	F	64		520	23 mg/liter Hitec 580 & 0.2% DiEGME	1	1.5	Experimental Element from manufacturer F; Element Rupture

Ref	Element	MSEP	Stadis 450 Conc. (ppm)	Stadis 450 k (pS/m)	Additives	Water Influent (%)	Water Effluent (ppm)	Comments
1	G	64		520	23 mg/liter Hitec 580 & 0.2% DiEGME	1	2.0	API Element from Manufacturer G; Note All API elements 6" OD and 11" Long
1	H	64		520	23 mg/liter Hitec 580 & 0.2% DiEGME	1	4.0	API Element from Manufacturer H
1	J	64		520	23 mg/liter Hitec 580 & 0.2% DiEGME	1	2.0	API Element from Manufacturer J
2	Velcon TE95-110	64	3.5	547	None	0.01	1.0	Test Element of 85 Series
2	Velcon TE95-110	64	3.5	547	None	3	5.0	Test Element of 85 Series
2	Velcon I-65485TB	69	3.5	612	None	0.01	1.5	API Test Series 2; run 3
2	Velcon I-65485TB	69	3.5	612	None	3	4.0	API Test Series 2; run 3
2	Velcon TE95-110	64	3.5	547	None	0.01	2.0	API Test Series 3 Run 3
2	Velcon TE95-110	64	3.5	547	None	3	4.0	API Test Series 3 Run 3
3	Facet CC-N19SB-1	47	1	267	16 ppm Hitec 580	0.01	2.0	API Test Series 3, Run 3
3	Facet CC-N19SB-1	47	1	267	16 ppm Hitec 580	3	4.0	API Test Series 3, Run 3
3	Facet CC-F6-3SB	51	3	574	2.9 ppm Hitec 580	0.01	0.0	API Test Series 3, Run 3
3	Facet CC-F6-3SB	51	3	574	2.9 Hitec 580	3	0.5	API Test Series 3, Run 3
3	Facet CC-F6-3SB	42	3	600	None	0.01	0.0	API Test Series 1
3	Facet CC-F6-3SB	42	3	600	None	3	1.0	API Test Series 1
3	Facet CC-F6-3SB	49	3	600	None	0.01	0.0	API Test Series 2
3	Facet CC-F6-3SB	42	3	600	None	3	0.0	API Test Series 2
3	Facet TEC-4998	61	1	241	2.9ppm Hitec 580	0.01	0.0	API Test Series 3
3	Facet TEC-4998	61	1	241	2.9ppm Hitec 580	3	1.0	API Test Series 3
3	Facet TEC-4998	52	3.5	828	2.9ppm Hitec 580	0.01	1.0	API Test Series 3
3	Facet TEC-4998	61	1	241	2.9ppm Hitec 580	3	2.0	API Test Series 3
3	Facet TEC-4998	31	6	1392	4ppm Hitec 580	0.01	1.0	API Test Series 3
3	Facet TEC-4998	61	6	1392	2.9ppm Hitec 580	3	5.5	API Test Series 3
4	Velcon TE92-106	62	3.5	960	2.9 ppm Hitec 580	0.01	5.0	API Test Series 3
4	Velcon TE92-106	62	3.5	960	2.9 ppm Hitec 580	3	7.0	API Test Series 3
15	Velcon Military	84	3.5		None	3	10.0	API Test Series 2
15	Velcon Military	84	3.5		2.9 ppm Hitec 580	3	2.0	API Test Series 3
15	Velcon Military	92	3.5		None	3	10.0	API Test Series 2
15	Velcon Military	83	3.5		2.9 ppm Hitec 580	3	3.0	API Test Series 3
15	Velcon Military	81	3.5		None	3	9.0	API Test Series 2
15	Velcon Military	84	3.5		2.9 ppm Hitec 580	3	2.0	API Test Series 3

Table B.3 -- ASA-3 Data

Ref	Element	MSEP	ASA-3 Conc. (ppm)	ASA-3 k (pS/m)	Additives	Water Influent (%)	Water Effluent (ppm)	Comments
5	TE92-90	95	0.75	300		0.01	1	API 1581 Test Series 1
5	TE92-90	93	0.75	310		3	1.5	API 1581 Test Series 1
5	Velcon I-63387TB	87	0.75	420		0.01	1.5	API 1581 Test Series 2
5	TE92-90	95	0.75	300		3	1.5	API 1581 Test Series 2
5	TE92-90	95	0.75	530	2.9ppm Hitec 580	0.01	3	API 1581 Test Series 3
5	TE92-90	95	0.75	540	2.9ppm Hitec 580	3	7	API 1581 Test Series 3
6	Velcon I-63385TB	65	0.75	610	2.9ppm Hitec 580	0.01	3	API 1581 Test Series 2
6	Velcon I-63385TB	65	0.75	610	2.9ppm Hitec 580	3	6	API 1581 Test Series 2
6	TE90-62	69.5	0.75	610		0.01	4	API 1581 Test Series 1
6	TE90-62	69.5	0.75	610		3	7	API 1581 Test Series 1
6	TE90-62	58	0.75	540	2.9ppm Hitec 580	0.01	4	API 1581 Test Series 3
6	TE90-62	58	0.75	540	2.9ppm Hitec 580	3	6	API 1581 Test Series 3
7	Faudi F.3 - 305	94	0.75	440		0.01	1	API 1581 Test Series 1
7	Faudi F.3 - 305	94	0.75	440		3	2	API 1581 Test Series 1
7	Faudi F.3 - 965	96	0.75	440		0.01	2	API 1581 Test Series 2
7	Faudi F.3 - 965	96	0.75	440		3	6	API 1581 Test Series 2
7	Faudi F.3 - 965	94	0.75	600	2.9ppm Hitec 580	0.01	1	API 1581 Test Series 3
7	Faudi F.3 - 965	94	0.75	600	2.9ppm Hitec 580	3	3	API 1581 Test Series 3
8	Faudi F.3 - 305	94	0.75	410		0.01	2	API 1581 Test Series 1
8	Faudi F.3 - 305	94	0.75	410		3	3	API 1581 Test Series 1
8	Faudi F.3 - 965	92	0.75	450		0.01	2	API 1581 Test Series 2
8	Faudi F.3 - 965	92	0.75	450		3	5	API 1581 Test Series 2
8	Faudi F.3 - 965	98	0.75	540	2.9ppm Hitec 580	0.01	3	API 1581 Test Series 3
8	Faudi F.3 - 965	98	0.75	540	2.9ppm Hitec 580	3	6	API 1581 Test Series 3
9	Velcon I-63387TB	88	0.75	430		0.01	3	API 1581 Test Series 1
9	Velcon I-63387TB	88	0.75	430		3	3	API 1581 Test Series 1
9	Velcon I-63387TB	87	0.75	450		0.01	2	API 1581 Test Series 2
9	Velcon I-63387TB	87	0.75	450		3	4	API 1581 Test Series 2
9	Velcon I-63387TB	75	0.75	540	2.9ppm Hitec 580	0.01	2	API 1581 Test Series 3
9	Velcon I-63387TB	75	0.75	540	2.9ppm Hitec 580	3	4	API 1581 Test Series 3
10	Facet TEC 4474	76	0.75	860	2.9ppm Hitec 580	0.01	2	API 1581 Test Series 3
10	Facet TEC 4474	76	0.75	860	2.9ppm Hitec 580	3	5	API 1581 Test Series 3
10	Facet TEC 4472	89	0.75	601		0.01	3	API 1581 Test Series 1
10	Facet TEC 4472	89	0.75	622		3	3	API 1581 Test Series 1
10	Facet CC-N29	94	0.75	870		0.01	2	API 1581 Test Series 2
10	Facet CC-N29	94	0.75	840		3	2	API 1581 Test Series 2
11	Facet CA14-3	97	0.75	640		0.01	2.5	API 1581 Test Series 1
11	Facet CA14-3	97	0.75	640		0.5	5	API 1581 Test Series 1
11	Facet CA28-3	97	0.75	640		0.01	2	API 1581 Test Series 2
11	Facet CA28-3	97	0.75	640		0.5	6	API 1581 Test Series 2
11	Facet CA14-3	86	0.75	652	2.9ppm Hitec 580	0.01	4	API 1581 Test Series 3
11	Facet CA14-3	86	0.75	652	2.9ppm Hitec 580	0.5	7	API 1581 Test Series 3
12	Facet CA15-3SB	97	0.75	770		0.01	1.5	API 1581 Test Series 1
12	Facet CA15-3SB	97	0.75	789		0.5	4	API 1581 Test Series 1
12	Facet CA29-3SB	97	0.75	723		0.01	4	API 1581 Test Series 2
12	Facet CA29-3SB	97	0.75	758		0.5	9	API 1581 Test Series 2
12	Facet CA15-3SB	86	0.75	758	2.9ppm Hitec 580	0.01	2	API 1581 Test Series 3
12	Facet CA15-3SB	86	0.75	758	2.9ppm Hitec 580	0.5	4	API 1581 Test Series 3
13	Facet CA14-3	97	0.75	741		0.01	3	API 1581 Test Series 1
13	Facet CA14-3	97	0.75	789		3	7	API 1581 Test Series 1
13	Facet CA48-3	97	0.75	715		0.01	9	API 1581 Test Series 2
13	Facet CA48-3	97	0.75	758		10	10	API 1581 Test Series 2
13	Facet CA14-3	86	0.75	730	2.9ppm Hitec 580	0.01	5	API 1581 Test Series 3
13	Facet CA14-3	86	0.75	730	2.9ppm Hitec 580	10	5.5	API 1581 Test Series 3
14	Facet CA14-3SB	96	0.75	543		0.01	3	API 1581 Test Series 1
14	Facet CA14-3SB	96	0.75	549		5	7	API 1581 Test Series 1
14	Facet CA14-3SB	88	0.75	567	2.9ppm Hitec 580	0.01	4	API 1581 Test Series 3
14	Facet CA14-3SB	88	0.75	567	2.9ppm Hitec 580	3	7	API 1581 Test Series 3

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